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Photovoltaics Efficiency on Automatic Fish Feeding Distributors Device Using Internet of Things

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Abstract. Renewable energy is crucial for facilitating the shift towards a more sustainable society. It plays a significant role in establishing a clean energy system, mitigating greenhouse gas emissions, and enhancing the well-being of both current and future generations. The study included field observation and data analysis approaches. The study utilized IoT-based automatic fish feed spreaders, photovoltaic units, batteries, SCC (solar charge controller), Android phones, thermometers, multimeter tester, LCDs, ultrasonic sensors, and a microcontroller circuit. This study aims to acquire power, electrical energy, and efficiency measurements from solar systems employed in an Internet of Things (IoT) enabled automatic fish feeder apparatus. The results show that the power consumption needed to operate the IoT-based automatic fish feeder gadget is 48.75 watts. The peak of solar irradiance was recorded at 12.00 WIT, averaging 900.27 W/m^2. The lowest intensity was at 09.00 WIT, averaging 422.78 W/m^2. Photovoltaics can produce electrical power at 22.75 watts per hour, leading to a daily electrical energy output of 159.25 Wh. The highest photovoltaics efficiency was 16.37% with 465.3 W/m^2 of solar irradiance, 30.7 ^{o}C of temperature and 2.144 m/s of wind speed. The temperature and wind speed has significantly affected on photovoltaics efficiency.

1 Introduction

Fish farming has gained significant popularity among the general public in recent times. In addition to serving as a recreational activity, fish farming has emerged as a viable economic source for several communities. Optimal outcomes in fish cultivation necessitate meticulous management and attentive maintenance, just as feeding does. Feeding fish is typically performed manually by utilizing human effort to distribute them into ponds. This endeavour demands a substantial amount of time and effort. Additionally, it is imperative to perform this task consistently during the morning, afternoon, and evening. Hectic daily routines can occasionally disrupt the feeding process or even decrease the frequency of feeding programs.

Semi-automated feeding is accomplished using a feeder apparatus positioned above the pond within a circular receptacle. The container is fitted with an automated valve that the fish can activate at will by manipulating a stone connected to the valve via a thread. When the fish experiences hunger, it will intuitively manipulate the stone to trigger the opening of the feeding valve, resulting in food release. Fish farmers are dissatisfied with semi-mechanical feeding since it relies solely on fish instincts, which ultimately hampers fish growth. Automatic fish feeders can distribute fish food in precise amounts, which helps improve efficiency and support the goals of fish farmers [1].

Several automatic fish feed dispensers have been created, although they continue relying on PLN energy as their primary power source. Solar panels offer an alternate electrical power source, particularly in rainy environments where reliance on PLN electricity may exacerbate the condition. The earlier fish-feeding device, developed by [1], operated in an automated manner by establishing a feeding schedule based on time and utilizing a 12-volt battery as its power source. However, recharging the battery required electricity from the public power grid (PLN). In a study by [2], two 40Wp solar panels were installed on the fish thrower at an inclination angle of 10 degrees. The panels generated a power output of 12.80 watts. However, the equipment was not operated via the Internet of Things (IoT).

The Internet of Things (IoT) concept is propelled by technical advancements such as intelligent sensors, wireless connection, cloud computing, and data analytics. An extensive network enables the collection, analysis, and utilization of data created by diverse devices. This data can enhance efficiency, comfort, and security in different domains, including industry, transportation, health, agriculture, and the environment [3].

An analysis is necessary to calculate the energy requirements of a gadget that utilizes artificial intelligence powered by photovoltaics. This energy analysis aims to ascertain the energy utilization ratio and the required energy quantity [4, 5]. Energy analysis is necessary to identify potential energy savings and

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alternative options to replace fossil fuels [6, 7], particularly in fish breeding ponds that lack access to electricity from PLN. An energy diagnosis enables the identification of the energy distribution pattern, allowing for determining the daily energy requirements for equipment operation.

This study aims to obtain the required energy for an IoT-based fish feed dispensing device, which has already been developed. This device aims to assist fish farming entrepreneurs in addressing challenges related to the provision and timing of feed in ponds lacking an electrical power source to utilize the tool; electricity is required.

2 Materials and Methods

2.1 Materials

The study utilizes IoT-based automatic fish feeding spreaders, photovoltaic units, batteries, SCC (solar charge controller), Android phones, thermometers, LCDs, ultrasonic sensors, and a microcontroller circuit. The material utilised was fish feed, which is intended to be discarded into fish breeding ponds. The dimensions of the devices are as follows: length is 115.5 cm, width is 55 cm, and height is 145 cm; mass: 67 kg; fuel type: Battery; motor speed: 1200 rpm, 0.21 HP; output gearbox speed 90 rpm (0.13 HP, 60 cm of diameter); capacity: 50 kg; the operational productivity is 47.96 kg per hour.

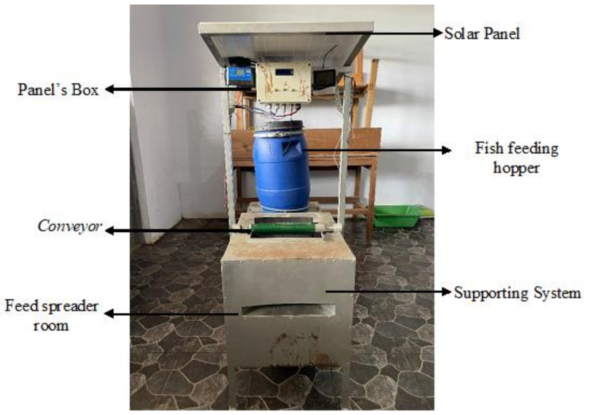


Fig. 1. The apparatus of automatic fish feed distribution

2.2 Methods

The research employed the methodology of field observation and subsequent data analysis. The research utilizes primary data and secondary data. Primary data is acquired through the process of conducting direct computations. Activate the tool by pressing the power button. Establish a feeding regimen through the application at 09.00, 14.00, and 20.00 Western Indonesia Time (WIT) at Jalan Dusun Sedar, Galang District, Deliserdang district, North Sumatra, Indonesia, with each feeding session lasting 8.3 minutes per schedule or 25 minutes per day. Utilize a thermometer to gauge the temperature at the feeding site. While for global solar radiation and wind speed was collected from BMKG (Meteorological, Climatological, And Geophysical Agency) for Deliserdang district. Analyze and compute the energy expended by tools in supplying and distributing food to fish breeding ponds then determine the photovoltaic efficiency using Equation (1).

$$\eta 0 = \frac{Pout}{Pin} \text{ x } 100\% \tag{1}$$

$$\eta = \eta 0 - (\alpha \times \Delta T) \tag{2}$$

The variables in the equation are defined as follows: η0 represents the photovoltaic efficiency in percentage, Pout represents the electric power produced by photovoltaic (Equation 3) in watts, Pin represents the received sunlight power (Equation 4) in watts, η represents the photovoltaic efficiency at a specific temperature, α represents the temperature coefficient of 0.4%/°C, and ΔT represents the temperature difference between the actual operating temperature and the theoretical temperature of 25 degrees Celsius [8]. To determine the level of efficiency achievable by photovoltaics at a specific temperature, Equation 2 can be employed.

$$Pout = V \ x \ I \tag{3}$$

$$Pin = F \ x \ Ac \tag{4}$$

The symbol V represents the electric potential difference (V). I represent the magnitude of the electric current (A). F represents the intensity of sunlight (W/m^2). Ac represents the surface area of the photovoltaic system (m^2).

3 Results and Discussion

3.1 Solar irradiance

Table 1 shows the solar irradiance from June 13 to June 18, 2023, starting from 09.00 until 15.00. The peak intensity was recorded at 12.00 WIT (Fig. 2), averaging 900.27 W/m^2. The lowest intensity was seen at 09.00 WIT, averaging 422.78 W/m^2. The solar radiation begins to rise at about 10.00 until 12.00 WIT and declines at 13.00 WIT.

Conversely, the lowest solar intensity was observed on June 14, 2023 (453.21 W/m^2). The diminished solar irradiance on June 14 and 16 is attributable to the prevailing weather conditions. Specifically, on those dates in 2023, at Jalan Dusun Sedar, Galang District, there was a more excellent cloud cover than on other days. The presence of clouds obstructs the incoming sunlight, reducing the energy output of photovoltaic systems. The intensity of sunshine is the primary determinant in converting solar energy into electrical energy [9].

Table 1. Sunlight intensity measurement data.

Time	**Solar irradiance (W/m^2)**						**Avg**
	13	**14**	**15**	**16**	**17**	**18**	

	June	June	June	June	June	June	
09.00	531.1	293.5	514.1	206	526.7	465.3	422.8
10.00	690.0	497.5	695.5	318.6	700.1	552.7	575.7
11.00	690.0	384.9	874.4	877.5	806.6	822.1	742.6
12.00	904.1	767.4	894.6	957.9	833.3	1044.3	900.3
13.00	820.7	547.3	834.8	902.1	933.3	812.2	808.4
14.00	804.7	358.8	751.9	899.7	890.6	701.6	734.6
15.00	631.3	323.1	544.3	407.1	188	548.8	440.4
Avg.	724.6	453.2	729.9	652.7	696.9	706.7	

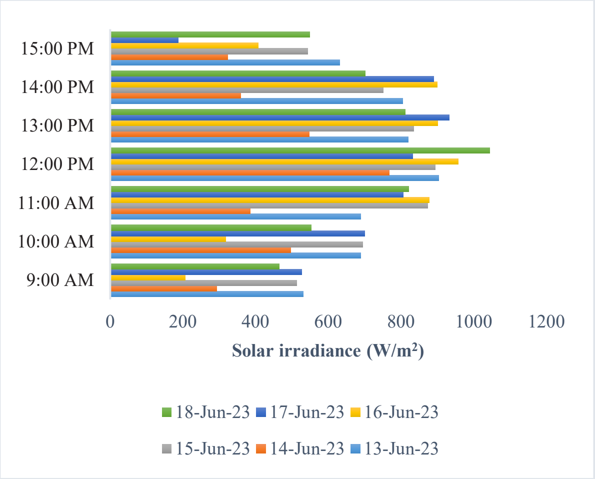


Figure 2. The relationship between time and solar irradiance

3.2 Temperature

Table 2 displays significantly elevated temperature readings, with the highest recorded temperature of 37.55 ˚C at 14.00 WIT and the lowest recorded temperature of 29.48 ˚C at 09.00. The average daily temperature is calculated to be 35.093 ˚C. The mean temperature in western Indonesia varies between 25 and 35 ˚C. Temperature contributes to the decline in photovoltaic efficiency during energy conversion. [10, 11] reported that elevated temperatures decreased photovoltaic efficiency, resulting in a drop of 0.4% per degree Celsius [12]. The best conditions for maximum efficiency are a temperature of 25 degrees Celsius and a sunshine intensity of 1000 watts per square meter.

Table 2. Data on environmental temperatures

Time	Temperature (˚C)						Avg.
	13 June	14 June	15 June	16 June	17 June	18 June	
09.00	28.5	29.0	30.1	28.8	29.8	30.7	29.48
10.00	33.0	34.9	35.7	34.0	33.7	31.6	33.82
11.00	36.5	31.1	37.3	36.5	34.9	36.0	35.38
12.00	39.6	33.0	37.7	36.3	37.9	37.0	36.92
13.00	39.2	32.1	37.3	38.6	37.2	36.5	36.82
14.00	39.5	33.3	37.8	40.4	37.3	37.0	37.55
15.00	38.8	32.5	38.8	33.3	33.6	37.1	35.68
Avg.	36.4	32.2	35.9	35.7	35.1	34.8	

3.3 Wind

According to the data presented in Table 3, the maximum wind speed recorded was 3.337 m/s on June 14, while the minimum wind speed was 0 m/s on June 16 and on 18 June. Various elements, such as barometric pressure, altitude, latitude, and others, can influence both the speed and direction of wind. The efficiency of photovoltaic electricity generation is influenced by the direction and speed of the wind. To enhance the efficiency of solar systems, it is important to consider both the direction and velocity of the wind that reaches the photovoltaic panels. However, to ascertain the optimal orientation for a photovoltaic site, it is necessary to conduct measurements of both wind speed and direction at the designated area for the installation. According to [9], environmental factors such as temperature and wind direction might impact the utilisation of photovoltaic power facilities. According to [9], an increase in wind velocity by 5.8 m/s (20 km/h) has contributed to a reduction in module temperature by 12 ºC. Consequently, this has resulted in a 7.2% increase in power generation and a 6.5% enhancement in efficiency. In addition, the south wind facilitated more effective cooling, resulting in a temperature decrease of 13 ºC and a 5.7% rise in power. Hence, it is imperative to take into account these aspects to ascertain the optimal orientation for the placement of photovoltaic systems. Nevertheless, the correlation between wind direction, speed and the efficiency of photovoltaics is minimal in this study, so indicating that these factors do not significantly affect the absorption of solar energy by photovoltaic systems.

Table 3. Wind speed data

Time	Wind speed (m/s)						Avg.
	13-June	14-June	15-June	16-June	17-June	18-June	
9	3.275	3.337	3.304	2.475	3.764	2.144	3.05
10	3.33	1.775	2.765	3.143	2.25	2.267	2.59
11	1.586	1.792	1.742	1.343	2.369	1.935	1.79
12	0.677	1.127	0.014	0.139	0.278	0.807	0.51
13	0.614	0.955	0.2	0.621	0.479	0.14	0.50
14	1.014	0.318	0.017	0	0.911	0.157	0.40
15	0.041	1.31	0.757	0	1.063	0	0.53
Avg.	1.51	1.52	1.26	1.10	1.59	1.06	

3.4 Electricity

The photovoltaic output electrical power is determined by the product of the voltage and electric current generated by the solar system, which is influenced by the intensity of sunlight received. The measurements were conducted from June 13 to 18, 2023. Table 5 displays the outcomes of the electrical power generated. According to Table 5, the maximum average power was recorded on June 18, 2023, with a value of 30.58 W, while the minimum average power was observed on June 16, 2023, with a value of 8.47 W. According to Table 5, the highest of output power is at 12.00 PM due to at this time is the peak of solar irradiance. The power generated by photovoltaics is determined by the level of solar irradiance and the surface area of the photovoltaic system. The power output of photovoltaics is influenced by the intensity of sunshine and the cross-sectional area of the photovoltaic cells. The intensity of incoming sunlight primarily influences the conversion of solar energy into electrical energy, and the cross-sectional area of a photovoltaic means a higher intensity of incoming sunlight and a broader cross-section of a photovoltaic result in a greater power generation capacity [13].

The intensity of sunlight is determined by multiplying the photovoltaic area by the intensity of sunlight. At the same time, the input power is calculated by multiplying the voltage and current generated by the solar system.

Table 4. Input electric power (P_{in})

Time	**P_{in} (W)**						
	13 June	**14 June**	**15 June**	**16 June**	**17 June**	**18 June**	**Avg.**
09.00	192.2	106.2	186.0	74.5	190.6	168.4	152.9
10.00	249.6	180.0	251.6	115.3	253.3	199.9	208.3
11.00	249.6	139.3	316.4	317.5	291.8	297.4	268.7
12.00	327.1	277.7	323.7	346.6	301.5	377.8	325.7
13.00	296.9	198.0	302.0	326.4	337.7	293.9	292.5
14.00	291.1	129.8	272.0	325.5	322.2	253.8	265.8
15.00	228.4	116.9	196.9	147.3	68.0	198.6	159.4
Avg.	262.1	164.0	264.1	236.2	252.2	255.7	239.0
Input energy (E_{in}) (Wh)	1,835.0	1,147.8	1,848.7	1,653.0	1,765.1	1,789.8	

Table 5. Output electric power (P_{out})

Time	**P_{out} (W)**						
	13 June	**14 June**	**15 June**	**16 June**	**17 June**	**18 June**	**Avg.**
09.00	2.43	4.38	27.13	5.64	29.03	27.56	16.03
10.00	29.96	23.92	33.22	17.16	33.55	30.67	28.08
11.00	33.62	6.39	36.96	12.85	38.25	32.38	26.74
12.00	36.98	15.26	30.40	11.23	40.81	35.26	28.32
13.00	35.92	8.24	36.30	3.64	29.90	41.50	25.91
14.00	33.66	8.82	24.82	3.07	23.40	22.20	19.33
15.00	25.78	5.66	22.88	5.68	4.56	24.48	14.84
Avg.	28.33	10.38	30.24	8.47	28.50	30.58	22.75
Output energy (E_{out}) (Wh)	198.34	72.66	211.71	59.26	199.49	214.04	

Output power is the result of multiplying the voltage (V) by the electric current (I) produced by photovoltaics. On the other hand, input power is the expected power generated from solar energy received by photovoltaics. Figure 2 demonstrates a direct proportionality between the input power (Pin) (W) and the output power (Pout) (W), with a correlation coefficient (R^2) of 0.2793 or 27.93 %. This indicates that 27.93% of the power received by the photovoltaic system affects the power produced by it.

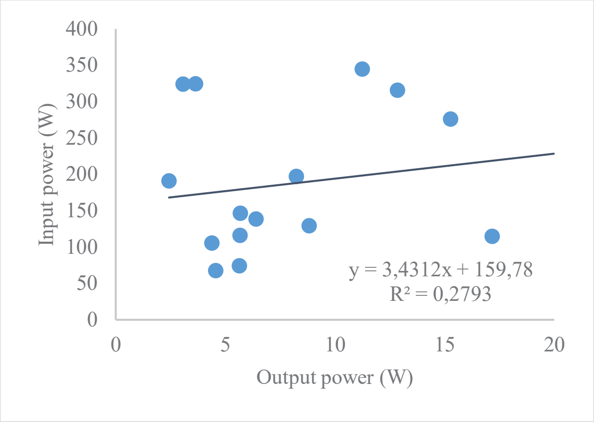


Fig. 2. The apparatus of automatic fish feed distribution

According to Table 4, the most significant amount of electrical energy generated was recorded on June 18, 214.25 Wh. This coincided with the highest level of sunshine intensity, as indicated in Table 1, which also occurred on June 18, 2023. On the other hand, the lowest energy production was observed on June 16, with a value of 59.26 Wh. The minimum solar irradiance was also observed on June 16, 2023. The energy production of photovoltaics is directly proportional to the amount of sunshine they get. This is because silicon in photovoltaics allows it to function as an insulator at low temperatures and as a conductor when exposed to heat energy from light. The sun generates an average electrical energy of 159.25 Wh using photovoltaics for 7 hours daily.

The IoT-based automatic fish-feeding system and its microprocessor necessitate a power input of 48.75 W. The tool can dispense fish feed weighing 6 kg within 8.3 minutes. If the tool is used for feeding three times a day, it will function for a total of 0.417 hours daily. The IoT-based automatic fish-feeding gadget consumes 20.33 Wh of electrical energy daily. The equipment's electrical energy requirements have been satisfied by the average electrical energy generated by photovoltaics, which the lowest is 59.26 Wh (Table 5). The surplus electrical energy of 148 Wh is directed to the battery as a reserve power source when the photovoltaic system is not generating electricity at the required rate for the device.

The IoT-based automatic fish-feeding equipment and microcontrollers are powered by a battery that is charged by the absorption of solar energy, which is not available during rainy or nighttime conditions. The battery has a capacity of 70 ampere-hours (Ah) or 840 watt-hours (Wh). When fully charged, it can run the device for around 17.23 hours, assuming no energy is generated by photovoltaics. Nevertheless, [14] has asserted that over 80% battery capacity usage might lead to rapid battery deterioration, and recharging should be done when the battery has depleted 50% of its capacity to prolong its lifespan. By performing the calculation, one can determine the product of the number of batteries and the battery efficiency, which is 50%. Consequently, the battery usage during periods without sunlight amounts to 8 hours, thereby extending the battery's lifespan.

3.5 Photovoltaic Efficiency

The photovoltaic efficiency was determined by comparing the output power (Pout) (W) from Table 5 with the input power (Pin) (W) presented in Table 4. Table 6 reveals that the peak efficiency of 16.37% was seen on June 18, while the lowest efficiency of 13.29% happened on June 14. Theoretical efficiency of solar panel can achieve 18.72% (Table 7). The power conversion efficiency of a typical photovoltaic (PV) module is approximately 15% [15]. According to Table 6, the drop in photovoltaic efficiency was only 0.04% per degree Celsius. The effectiveness of photovoltaic systems is determined by two primary factors: the intensity of incoming sunlight and the cross-sectional area of the photovoltaic. Nevertheless, minor variables, such as ambient temperature, wind velocity, and wind direction, can also impact efficiency. [16, 17] reported that the photovoltaic capacity directly impacts the efficiency of converting solar energy into electricity and asserted a positive correlation between photovoltaic capacity and conversion efficiency. However, it is essential to note that this relationship can be altered by the specific technology and design of the panels being utilized. Greater photovoltaic capacity can generate increased electrical power compared to smaller capacity panels, particularly when exposed to ample sunshine. The photovoltaic capacity is determined by the system's physical parameters, precisely the solar cells' size and quantity. The size and shape of a photovoltaic module can impact its energy production capacity and the efficiency of its sunlight collection mechanism.

Table 6. Actual efficiency of solar panels

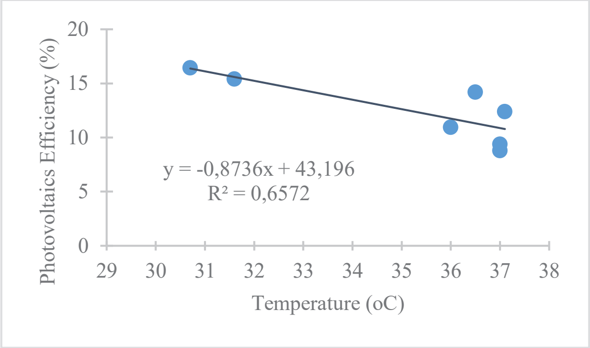
	Photovoltaic efficiency (%)						
Time	**13 June**	**14 June**	**15 June**	**16 June**	**17 June**	**18 June**	**Avg.**
09.00	1.26	4.12	14.59	7.57	15.23	16.37	9.86
10.00	12.00	13.29	13.20	14.89	13.25	15.34	13.66
11.00	13.47	4.59	11.68	4.05	13.11	10.89	9.63
12.00	11.30	5.50	9.39	3.24	13.54	9.33	8.72
13.00	12.10	4.16	12.02	1.12	8.85	14.12	8.73
14.00	11.56	6.79	9.12	0.94	7.26	8.74	7.40
15.00	11.29	4.84	11.62	3.85	6.70	12.33	8.44
Avg.	10.43	6.18	11.66	5.09	11.13	12.45	9.49
Max.	**13.47**	**13.29**	**14.59**	**14.89**	**15.23**	**16.37**	

Temperature is a significant component that impacts the efficiency of photovoltaics. As the temperature increases, the efficiency of the photovoltaic system decreases. In addition, as stated by [18], wind direction can also impact the rise in photovoltaic temperature. When the wind blows in the opposite direction of the back surface of the solar, it enhances the cooling efficiency of the panels. Nevertheless, when the wind originates from the rear side of the solar, it might lead to the entrapment of hot air in the vicinity of the panel, resulting in an elevation of the panel's temperature. Elevating photovoltaic temperatures can lead to a reduction in energy conversion efficiency and overall panel performance. This study found that temperature does not significantly affect photovoltaics efficiency, possibly because the actual temperature is over 25 ºC and sun irradiation, wind speed, and temperature vary.

Table 7. Theoretical efficiency of solar panels

	Photovoltaic efficiency (%)						
Time	**13 June**	**14 June**	**15 June**	**16 June**	**17 June**	**18 June**	**Avg.**
09.00	2.66	5.72	16.63	9.09	17.15	18.65	11.65
10.00	15.20	17.25	17.48	18.49	16.73	17.98	17.19
11.00	18.07	7.03	16.60	8.65	17.07	15.29	13.78
12.00	17.14	8.70	14.47	7.76	18.70	14.13	13.48
13.00	17.78	7.00	16.94	6.56	13.73	18.72	13.45
14.00	17.36	10.11	14.24	7.10	12.18	13.54	12.42
15.00	16.81	7.84	17.14	7.17	10.14	17.17	12.71
Avg.	15.00	9.09	16.22	9.26	15.10	16.50	13.53
Max.	**18.07**	**17.25**	**17.48**	**18.49**	**18.70**	**18.72**	

Figure 3 depicts the correlation between temperature and solar panel efficiency through a linear regression analysis, yielding an R^2 value of 0.6572 or 65.72%. This indicates that temperature directly impacts the efficiency of the solar device. In addition to solar irradiance, various minor factors affect the efficiency of photovoltaic systems. Although these factors may not significantly impact study outcomes wind speed. It is advisable to maintain an optimal temperature of 25 °C by cooling measures to mitigate the effects of wind on solar systems. On the other hand, according to Fig. 3, the correlation between wind speed and solar panel efficiency was 25.25%. Additionally, a protective design can safeguard the photovoltaic panels from high gusts that may bring dust particles, minimizing efficiency losses.



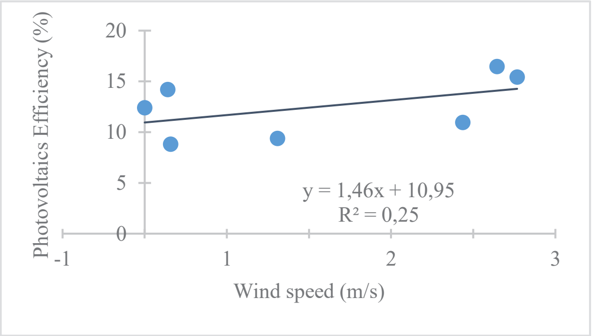


Fig. 3. The correlation among of photovoltaics efficiency with temperature and wind speed

4 Conclusion

The peak of solar irradiance was recorded at 12.00 WIT, averaging 900.27 W/m^2. The lowest intensity was at 09.00 WIT, averaging 422.78 W/m^2. The solar radiation begins to rise at about 10.00 until 12.00 WIT and declines at 13.00 WIT. The maximum average photovoltaic energy produced for 7 hours was 214.04 Wh on June 18, and 159.25 Wh from June 13-18, 2023. The automatic fish feeding spreaders based on IoT requires 48.75 W, and operating it for 0.417 hours (25 minutes) per day uses 20.33 W. The temperature and wind speed has significantly affected on photovoltaics efficiency. The highest photovoltaics efficiency was 16.37% with 465.3 W/m^2 of solar irradiance, 30.7 ºC of temperature and 2.144 m/s of wind speed. 50 Wp photovoltaics that capture solar energy for 7 hours per day can power an IoT-based automatic fish feeding device that uses 20.33 Wh. The solar device's efficiency is directly affected by only 27.93% of the incoming light intensity.

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